# CARBONACEOUS MATTER IN THE NAKHLA METEORITE


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Independent Study and Mentorship

Final Product

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# ABSTRACT

The idea that life could exist outside our planet seemed inconceivable. However, studies have shown indications that Mars may have been capable of fostering life for a certain time period. Recently, under the assistance of Dr. Kathie Louise Thomas-Keprta, I identified regions that had evidence of organic matter and water to further the implications of the development of life outside the Earth.

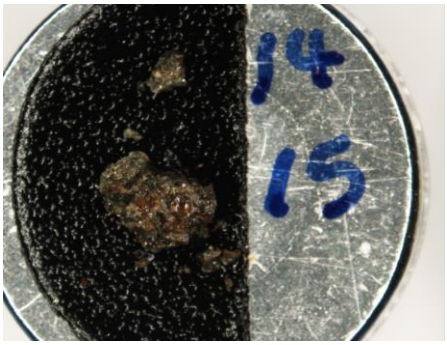
# HISTORY OF THE METEORITE

` On June 28, 1911, another gift from Mars impacted the surface of Earth. This time it landed in Egypt, rather than Antarctica. This was the first meteorite impact that was recorded in Egypt. Around forty fragments of Nakhla showered over the city and scientists almost immediately collected the samples and sent it to the Johnson Space Center for analysis. Some questions that individuals have about Nakhla is how did it get from Mars to Earth and also how astrobiologists figured out that the meteorite was from Mars. Scientists came up with the theory that stated if an extraterrestrial object impacts the martian surface and then debris reaches 5.5 kilometers per second, it has the capability to escape the atmosphere of Mars. Additionally, researchers looked back at the data from the Viking Landers to see if there was a correlation between Mars and Nakhla. Fortunately, they looked in the right place. The Viking Landers had analyzed the chemical composition of the martian atmosphere and this allowed the scientists back at NASA confirm that Nakhla was martian in origin due to its similar chemical composition.

Furthermore, the crystallization age of the meteorite was later revealed to be around 1.3 billion years old. The crystallization age essentially tells when the meteorite was formed on Mars. This is really important to understand because Earth doesn't have any rock that is billions of years old. This makes sense because the planet consists of plate tectonics. As a result, the Earth is constantly renewing itself (rock cycle). You don't have this geological phenomenon on Mars. Instead, the heating under the surface of Mars makes the surface stretch in various ways. While there is activity happening on Mars, it doesn't renew its rocks. With that said, the age of the rock also proved that it was not from Earth. Apart from this, through thorough analysis, scientists established that there was evidence of pre-terrestrial water and pre-terrestrial carbon. Nakhla had a large content of phyllosilicates within the internal part of the meteorite. Through Argon dating ($^{40}Ar$ - $^{39}Ar$), astrobiologists identified that the phyllosilicates were 700 millions years old, which is much younger than the meteorite. This shows us that phyllosilicates were put into the meteorite, while it was on Mars, proving the theory that Mars had pre-terrestrial water. In addition to this, scientists like Dr. Mckay used effective techniques to detect regions of carbonaceous matter in the Nakhla Meteorite. Scientists like Dr. Mckay called this technique the chocolate chip cookie analogy. This analogy discusses how it would be easier to pick out the chocolate chips from the cookie if it was all clumped together instead of being scattered across. This is exactly what Dr. Mckay did when he looked at NASA. Prior to his work, astrobiologists used stepped combustion methods to do analysis but that unfortunately destroyed the samples. The methods used for sample analysis has definitely evolved drastically.

# METHODS

My mentor and I used freshly fractured samples from Nakhla 14 and 15 and mounted them on an aluminum pin. We then put double sided carbon tape on half of the mount. The tape was utilized to prevent the meteorite samples from falling off the mount. Furthermore, we coated the samples with 2.2 nm of platinum. This would give an electrical charge for the sample. As a result, we would get accurate data from the scanning electron microscope. When it comes to the analysis of the samples, we used an Olympus BX 60 Optical Microscope and JEOL 6430F Scanning Electron Microscope, which is equipped with an Energy Dispersive X-Ray Spectrometer. This allowed us to take chemical spectra and maps.




*Samples of Nakhla 14 & 15 were mounted onto an aluminum pin. Double sided carbon tape was then used to cover half of the pin (black).*

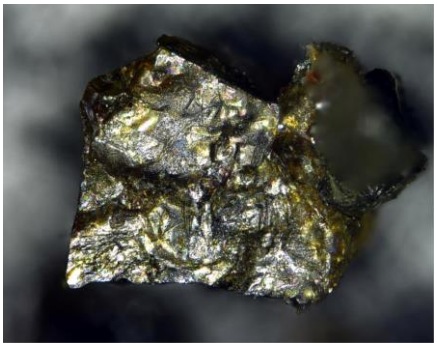


*Image of Nakhla 15 under the Optical Microscope.*

# RESULTS

One of the first things we found was a very unusual feature in Nakhla 15. The optical microscope showed a formation that was very unique to what we were used to seeing. It was

shaped like an upside down checkmark and contained yellow bushy structures. Both my mentor and I immediately started to investigate what exactly it was. We did this because in the past, scientists have identified unique formations to be the cause of biological processes.

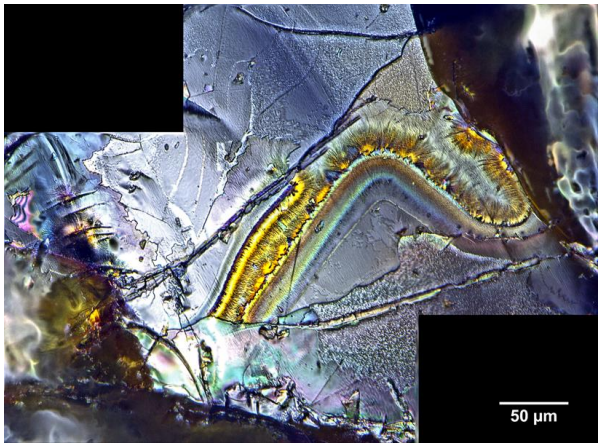
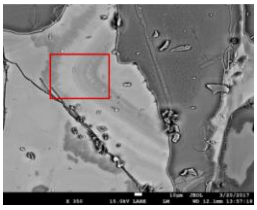
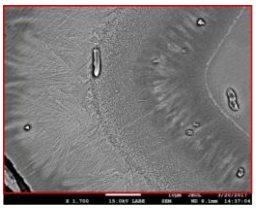


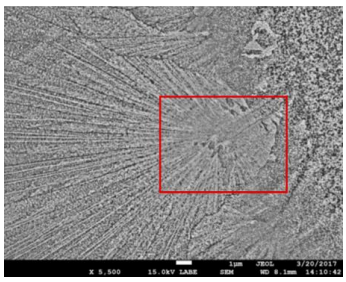

*Image from the optical microscope of the unusual Nakhla formation*

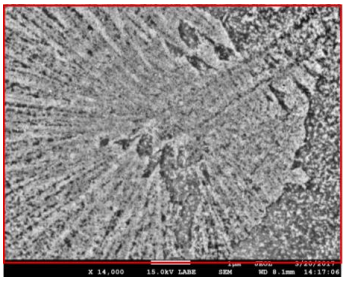
After the identification, my mentor and I used a high magnification on the scanning electron microscope to get a better look at the feature. The images below are the what we saw under high magnification. This allowed us to get a better understanding of what exactly we were looking at.





After we examined this region, we proceeded to investigate the bushy structures. Due to this, we used an even more higher magnification. What we found was interesting. After looking at these images for some time, it seemed like something was ejected in that feature, giving it the bushy like shape.





Further into the research, my mentor and I decided it was best if we did a chemical analysis on that region. This would tell us exactly what the feature was. We were hoping to find carbonaceous matter in that area but failed to do so. However, we found a large amounts of salts. This established what we were looking at. The feature was an unusual clay formation. The existence of clay supported the theory that Mars had water at some point.

Additionally, I started to look for textures that further suggested evidence of water. After some time looking through the Nakhla 15 sample, I found geographical region that was very interesting. This specific area consisted of five layers (made up of phyllosilicates) that showed signs of weathering, done by water. What makes it even more intriguing is the fact that each layer had a distinct texture from each other. This established that there were multiple episodes/periods of water flowing on Mars.

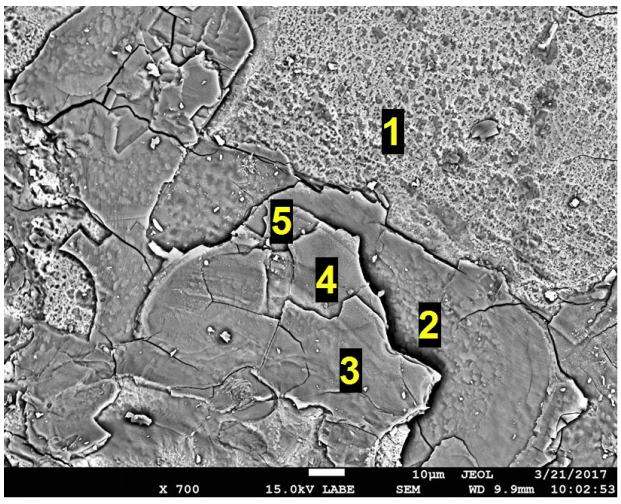
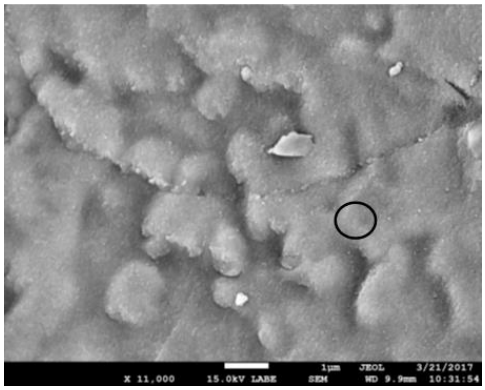
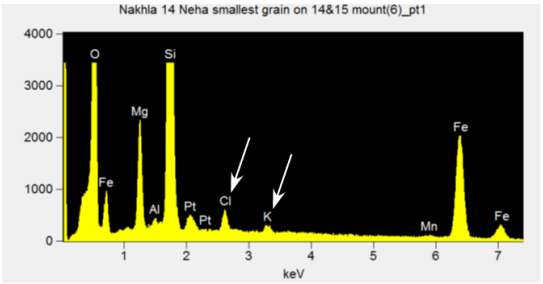
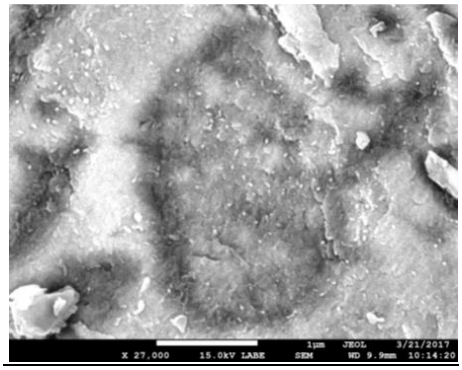


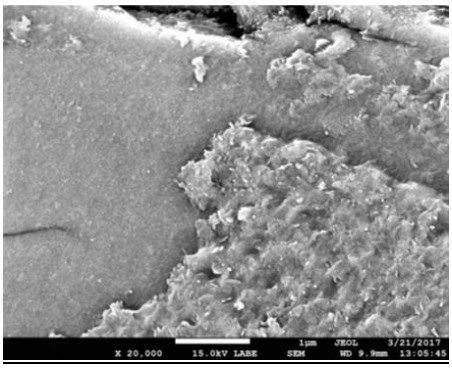

*Image from the SEM shows the five distinct layers in Nakhla 15*




*SEM image and chemical analysis of layer number 2 from the Nakhla 15 sample*

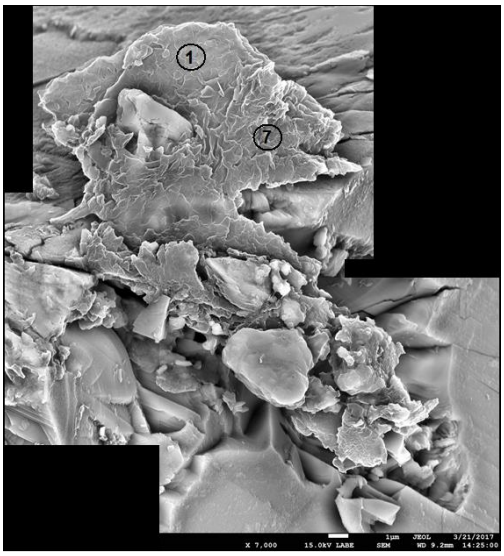


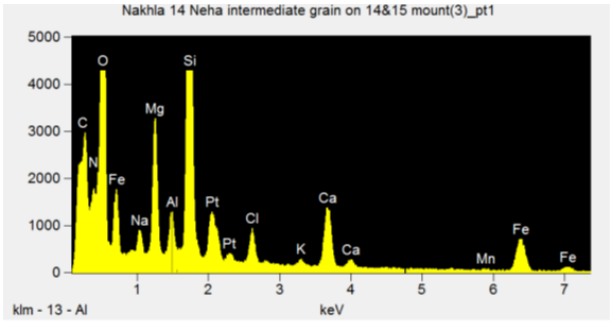

*SEM images of layer number 1 (left) and layer number 2 (right)*

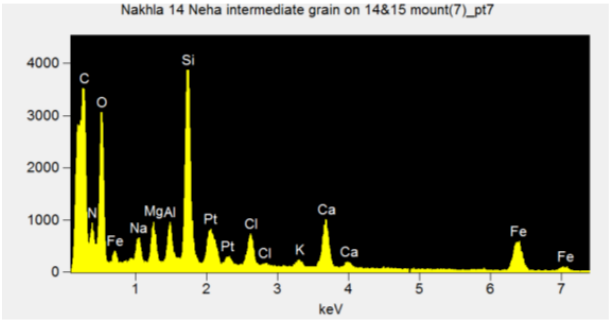
After doing extensive search on finding evidence of water, I proceeded to start looking for carbonaceous matter in the Nakhla 14 sample. My mentor and I did indeed find a region that contained large amounts of organic material. We were initially concerned about the placement of the organic matter because it was on the edge of the sample. This is usually an indication that the component is a contaminant. However, there are indigenous minerals that are engraved in the carbonaceous material, which proves that the organic matter is indeed native to the sample. After making this conclusion, my mentor and I did an EDX Spectra of the organic material. The spectra showed peaks in carbon, oxygen, and nitrogen. The peak in nitrogen is especially important because it is an element that is crucial to the development of life (DNA, RNA, nitrogen fixation, etc.). In addition to that, at the beginning of this year, my

mentor had found a large peak in nitrogen in a different Nakhla sample for the first time. So, because we found another peak in nitrogen in Nakhla 15, we can assert that nitrogen played a key role in Mars' biological past. I finished my final product by doing a chemical map on the organic substance to get an understanding of the spatial distribution of the chemical elements that made up the carbonaceous matter.

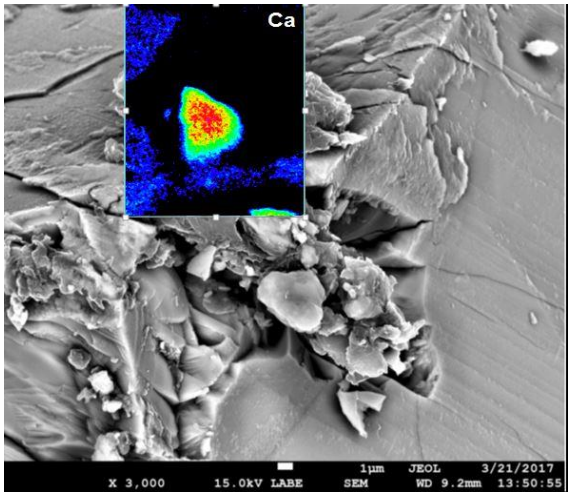



*SEM image of the carbonaceous matter found in Nakhla 14*

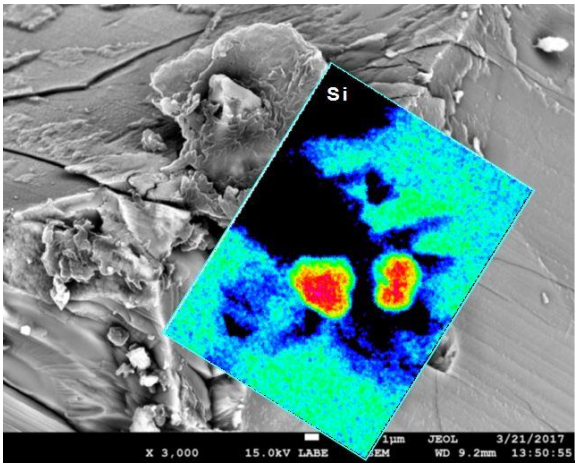


*EDX Spectra of the carbonaceous matter found in Nakhla 14*




*Chemical map of the calcite that is engraved into the organic material*




*Chemical map of the silicate minerals embedded into the organic material*

# Conclusion

Through the analysis of Nakhla 14 and Nakhla 15, my mentor and I had found multiple evidences that there was water and pre-terrestrial carbon on Mars. Despite this, there is still a lot of work to be done on this particular sample and we have to confirm that our results aren't

due to any contaminations. Furthermore, last month, my mentor's colleague, Dr. Everett Gibson gave a talk at the NASA Astrobiology Institute in April. The conference primarily revolved around the presence of boron in Nakhla salts and clay. Scientists at the conference concluded that boron may be an element that stabilizes RNA. A professor from Florida, who attended the conference was so interested in that work that he asked Dr. Keprta to send him the samples that we used in March for my final product. My mentor is going to take a FIB section from the five layered region that I found and send it to that professor for further analysis. This research marks a new beginning to understanding Mars.

# Citations


1. *Childs, Arcynta Ali. "One Hundred Years Ago Today, A Mars Meteorite Fell in a Blaze."Smithsonian.com. Smithsonian Institution, 28 June 2011. Web. 17 May 2017.*
2. *NASA. NASA, n.d. Web. 18 May 2017.*
3. *Breitman, Daniela. "Today in Science: Egypt's First Meteorite." EarthSky. N.p., n.d. Web. 18 May 2017.*